On some Parts of the Anatomy of *Ophiothrix variabilis*, Dunc., and *Ophiocampsis pellicula*, Dunc., based on materials furnished by the Trustees of the Indian Museum, Calcutta.

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[Read 3rd June, 1886.]

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I. *Distinctions between* Ophiothrix variabilis, *Dunc., and Lyman's type*, O. quinquemaculata, *Müll. & Trosch.*

The structures of the upper surface of the arms within the disk, the genital plates and scales, the mouth-frames and the dental apparatus, which are seen after clearing out the inside of the disk, are exceedingly interesting in *Ophiothrix variabilis* (Plate X. fig. 1), and it is evident that they differ somewhat from those of the species *O. quinquemaculata*, Müll. & Trosch., which was chosen by Lyman as his type of *Ophiothrix* (see Lyman's excellent figures, 'Challenger' Report, pl. xlii. figs. 5–8). In *O. variabilis* there are six arm-bones between the conjoined mouth-frames and the nodular heads of the genital plates, whilst in Lyman's type there are only four. In this type the upper parts of the first and second arm-bones are not very wide, but the corresponding parts of the first and second arm-bones of the Mergui form are wide; moreover, when the arms are straight the genital plates of the new form only reach inwards to the level of the second, or the interval between the second and third arm-bones, and not to the first arm-bone as in Lyman's type. When the arm is bent sideways and fixed so, after becoming dry, the genital plate of the inwardly curved side of the arm of course reaches further adorally in *O. variabilis*. The length of the genital plates of both forms is much the same, but the greater number of arm-bones in *O. variabilis*, placed adorally to the outer and more or less fixed part of the plates, permits of greater sideways-bending movements of the arms. The shape of the upper parts of the arm-bones is very similar in both species; perhaps the first plate is the larger in the

Mergui form, fig. 1, and it is Ophiothrician. The shape of the genital plates and scales is slightly different. There is a peristomial plate in Lyman's type, but not in *O. variabilis*.

II. *Mouth-frames, and Muscles*; *Jaw-plates*; *Teeth and Tooth-papillæ, and their Muscles.*

The aboral edge of the conjoined mouth-frames, seen from above, is broad, and their union is by a stout, upward projecting, long nodule (Pl. X. fig. 1). The edges of the mouth-frames on either side of the mouth-slit are upwards projecting and crescentic in their outline; but the arch formed at the mouth-slit is imperfect, there being a small outer indentation at the median line which gives, with the outlines of the brachial edges of the mouth-frames, a trefoil shape to the brachial extension of the mouth. The incurving close to the junction of the mouth-frames at the median line of the brachial region is small.

The width of the brachial area of the region of the mouth is limited by the comparatively radial direction of the jaws, and this direction evidently has some connection with the size of the space between the interbrachial edges of the mouth-frames in each interbrachial space. These opposed edges are long from within outwards, and slightly curved, and they are united by the fibres of the interradialis aboralis muscle. The mouth-frames much resemble those of *Ophiophragmus* as figured by Lyman in the 'Challenger' Report, plate xl. fig. 4.

It is evident that the distance between the interbrachial edges, and therefore between adjacent mouth-frames, can be increased or diminished by the action of the muscular fibres, and the distance does vary in the dead specimen. When the edges are far apart, the obliquity of the jaws from the radial direction is greater than when the edges are closer; when that is the case, the direction of the jaws is more radial. The jaws are rather long, and there is the usual well-marked depression for the vessels and nerves.

It will be noticed in the description of the underpart of the disk of the species (p. 99) that the side mouth-shields are not united together orally to the mouth-shields, and that a skin intervenes; moreover the separation along the median line of every jaw-angle is considerable. Hence there is a space which extends from the neighbourhood of the jaw-plate outwards between the side mouth-shields to the adoral edge of the mouth-shield. The skin of this

space is overlain, in the proper position of the animal, by a very thin muscular layer belonging to the interradialis aboralis, and the fibres are attached to the sides of the slit between the jaws, between the separated side mouth-shields, and between these last and the adoral edge of the mouth-shield.

Considering these lower and superficial muscular fibres as acting in combination with the stouter and higher ones of the interradialis, it follows that contraction or expansion of the interbrachial spaces can occur, aborally, to the jaws. The contraction, or the opposite condition, would increase or diminish, as the case might be, the radial direction of the jaws in relation to the jaw-plate, and would push this last inwards or the reverse. The movement of the jaws on the jaw-plate, however slight it might be, would influence the muscles which traverse the jaw-plate and are fixed on the outer or basal part of the teeth (Pl. X. fig. 3), as well as those which unite the approximated adoral ends of the mouth-frames—that is to say, the interradiales adorales superiores and inferiores.

Probably expansion or relaxation of the interbrachial muscles would produce an opposite condition of the tooth-muscles. During expansion, on account of the increased obliquity of the jaws in relation to the jaw-plates, the mouth-opening would slightly enlarge and the muscles of the teeth would be tightened, and the teeth would assume the horizontal position. With contraction there would be diminution of the space around the mouth, narrowing of the interbrachial areas, and relaxation of the tooth-muscles, accompanied by diminution of the size of the mouth.

The possible nature of these movements may be gleaned from the following details of the jaw-plates, teeth, and muscles.

The jaw-plate (torus angularis) is tall, broad and thin (fig. 2), and it projects slightly beyond the line of the sides of the jaws as well as above them and considerably below. It is a very distinct structure in this species, and it is broadest and most projecting inferiorly and rounded there, thence it slopes at the sides upwards and gradually diminishes in breadth as far as the spot where the true teeth commence. The upper part of the plate which gives attachment to the teeth is not as broad as the inferior portion, but it is rounded off above where it is free.

The oral surface of the plate is covered on the lower half by the 20 or 21 tooth-papillæ, and the upper half carries the four teeth.

When the papillæ and teeth are removed, a number of rather

regularly placed, elongate or circular, low projections become visible on the broad inferior portion of the plate; and on the upper part four vertical double rows of foramina. The double rows are separated by low horizontal ridges, and a median low ridge is placed vertically along the median line so as to separate the foramina into two lateral series. The foramina are large and pass quite through the jaw-plate (figs. 2 & 3).

The slightly expanded bases of the tooth-papillæ (fig. 4) cover the low projections, but the base of a tooth covers two of the horizontally placed foramina besides some of the surface of the ridges just above and below them (figs. 2, 3, 6). The outer, or rather the side, tooth-papillæ are usually with elongate bases, and are placed on correspondingly shaped projections which are more or less oblique, and the papillæ which are along the median line of the plate are upon wider apart and circular low knobs. The papillæ (fig. 4) have their bases hollowed out so as to fit the projections, and connective tissue unites them with the plate around the edges of the projections. The highest papillæ are two in number, and resemble a true tooth divided along the median line and with an incurved free edge (fig. 5). But there are really two papillæ, and their bases are wide and elliptical in shape; moreover each has a pair of depressions in the base, and the union with the jaw-plate is by connective tissue only along a wide space (fig. 2). No muscular structures are found connected with the tooth-papillæ.

The four teeth are long, broad and thick at the base. They are composed of opaque carbonate of lime except at their free, sharp, yet broad, edge, where the mineral is semitransparent (fig. 6). On separating the teeth from the jaw-plate, it will be observed that their bases are elliptical and broad as well as hollowed-out. There is a double hollowing, and each hollow corresponds with a foramen in the jaw-plate (fig. 2). The upper and lower edges of the bases rest on the ridges between the pairs of foramina.

A small muscle passes out of each foramen and is inserted at the hollow of the base of a tooth, so that a tooth has two muscles, one on each side of the median line, and the direction of the muscles is rather oblique (figs. 3 (*c*), 7).

It may be noticed in some specimens that the side rows of tooth-papillæ are close to their neighbours of the next plates, and that on turning the animal on its back a very decided funnel-

shaped space exists leading to the two large papillæ which come next to the true teeth. It is evident that whilst the two papillæ just noticed can come in contact by their free edges with those of the opposite jaw-plates, none of the other papillæ can ever touch their opposite and similar structures.

The tooth-papillæ do not therefore form any part of what has been inelegantly termed a "chewing-apparatus."

On removing the jaw-plate from the mouth-frames the adoral surfaces of the jaws are seen side by side (fig. 8). Each jaw surface is tall from below upwards, narrow from side to side, hollow along the median line inferiorly, and with four irregular depressions in the upper part.

The four depressions correspond to the four foramina of one side of the jaw-plate, and the long hollow with the aboral surface of the jaw-plate on one side of the median line. The depressions give attachment to the muscles which pass through the foramina of the plate and are attached to the bases of the teeth (fig. 3). The long hollow below is for connective tissue which unites the converging jaw-ends and also the jaw-plates, and the groove of the hollow is completed by the approximation of the jaws. But there are about seven minute hollows or pits on the interradial side of each jaw, close to the projecting part which is in contact with the jaw-plate, and as many minute grooves pass from them over the edge and reach the long hollow. They appear to have no connection with the seven side tooth-papillæ, and they give attachment to muscular fibres (interradiales adorales inferiores) and connective tissue which bind the side of the jaw-plate to the jaw. It is possible that slight sliding movements of the jaw-plate upon the jaw-ends are thus rendered possible. It is evident that the duty of the muscles (interradiales adorales superiores) which pass through the foramina is to make the teeth stick out from the jaw-plate perpendicularly to it, and allow them to move slightly upwards or downwards at their free edge during the period when contraction does not occur. Chewing is, however, not possible, but the process of filtering occurs.

III. *The Radial Shields, Genital Plates, Scales, and Muscles.*

The aboral end of the radial shield is rather narrow, is slightly separated from that of the other shield, and projects over an aboral ridge of the genital plate, and both are placed well over the

upper surface of the arm. On turning the radial shield up and separating it from the head of the genital plate, the following structures are seen (Pl. X. fig. 9). Close to the aboral edge is a short curved, transverse space which gives attachment to a rather broad, thin muscle (*r*), which passes downwards and is inserted into a corresponding space on the aboral and upper end of the genital plate (fig. 11, *r*). This extensor muscle passes aborally to a downward projection of the radial shield, and also to the globose head of the genital plate, and it is covered with thin skin (figs. 10, 11). Adorally to this space, on the under surface of the radial shield, is a downward projection resembling a slightly flattened hemisphere. Its lower, slightly flattened, and more or less curved surface articulates with the globiform head of the genital plate below (figs. 11, 13). Situated adorally to the projection on the under surface of the radial shield, and separated from it by a narrow transverse space, is a fan-shaped muscular attachment (fig. 9, *am*), the arch of the space being placed orally, and the chord of the arc being transverse and bounding the narrow transverse space for the perihæmal canal adorally. The muscular marking is large and the fibres pass downwards and slightly aborally, form a stout little mass, and again expand and are inserted into an expansion on the upper surface of a genital plate (figs. 9, 11, 13, *am*). This adductor muscle is very distinct, and is evidently capable of considerable extension during the contraction of the extensor, and of corresponding contraction when in positive action.

There is a very thin slip of fibres, which seems to be muscular, passing from the outer edge of the radial shield below, and on a line with the origin of the adductor, to the radial-shield side of the broad genital scale (fig. 12, *m*).

On removing the radial shield and looking downwards upon the upper surface of the arm, the genital plate is seen with the scale attached to the side remote from the arm. The genital plate is moderately long, longer than the scale (*gs*), but much narrower (figs. 12–15). It has a head not very unlike that of a human thigh-bone, continuous with a shaft by a broad neck, and at the interbrachial side of the neck is a nodular surface which has a little gibbosity for the articulation of the genital scale (figs. 13–15). Aborally to the nodular part, and extending beyond and below the head, is an expansion which ends aborally in the ridge already noticed as giving insertion to the extensor muscle (figs. 11, 12, 15). Situated orally to the head on the upper surface of the genital plate is a

raised, irregularly triangular surface (fig. 13), corresponding in size to the fan-shaped muscular impression on the underpart of the radial shield (figs. 9, 11). It is for the insertion of the adductor muscle (*am*). Orally to this muscular insertion the genital plate narrows, is sharply rounded, and ends in a blunt point. A transverse section of the genital plate made orally to the triangular surface is not circular in outline, although the plate seems to be cylindrical when seen from above ; it is more or less a bent curve in outline (fig. 15), and the outer surface, which looks towards the genital slit, is rounded and large, whilst the inner surface, which is in contact with the side of the arm, is not so large and is concave. Seen from below, the genital plate shows a furrow and the projection at the side of the raised part for the insertion of the adductor, a rather narrow rod-like oral end, and a decided enlargement aborally, the aboral edge being below the insertion of the retractor (fig. 14). A side view shows foramina close to the neck, the globose head, the projecting aboral ridge, the nodule for articulation with the scale, and a foramen on the shaft (fig. 15).

The genital scale (fig. 13) is long, wide, irregularly triangular, and boldly curved at its free interbrachial edge. The process for the junction or, rather, articulation with the genital plate is small, and has a slight concavity on its side towards the genital plate's convex projection (or there may be an indefinite nodule). The articulation is by an indefinite arrangement not worthy of the name of ball-and-socket, but belonging to that category. The free brachial edge of the genital scale, which extends from the projection to the oral end of the scale, is nearly straight, long, and thin. This edge bounds the genital slit on the interbrachial side. There is some part of the edge of the scale free, but most of the upper surface is covered by the derm of the disk and is only seen after dissection. The specimen which showed these details has a trace of a slip, apparently muscular (fig. 13), which arises on the genital plate close to the neck, and from the trochanter-like side projection close to the head ; it passes between the raised surface for the adductor and the projection for articulation with the genital scale and is inserted along the brachial edge of the scale just orally to the projection for articulation. The slip is very thin, and crosses over the outer end of the genital slit to reach the edge of the genital scale.

It is perfectly evident that the genital plate may have its position altered by the arm being depressed or elevated as much as is possible, and that the plate may be parallel with the arm, or may form a wide angle with it. The genital plate being on the side, and over the arm, may have the adductor relaxed so as to allow the radial plate and the dome of the disk to rise. It appears that under these circumstances the relative positions of the plate and scale alter, and that there must be a considerable movement of the scale on the pivot of the brachial projection.

A few small overlapping scales are placed on the interradial edge of the genital slits between the oral termination of the genital scale and a process which is in contact with the aboral edge of the mouth-shield. These processes appear, on a superficial examination, to be parts of the mouth-shields passing outwards in the interradial spaces, and limiting, orally, the derm of the underpart of the disk. Lyman has shown that they are really only closely attached to the mouth-shields with connective tissue, and maceration separates them. Each of these processes is double and each touches its fellow at the median line; they are broadly attached to the aboral edge of the mouth-shield and are collar-shaped. At the median line aborally their edges diverge, sloping outward and then towards the arm, and reaching the genital slit. The derm is attached to the edges of these processes, which are properly genital scales, instead of to the aboral edge of the mouth-shields.

IV. *The Structure of the Arm-bones.*

These are formed generally after the type of the Ophiothricidæ, as described and figured in Lyman's 'Challenger' Report on the Ophiuroidea (pl. xlii. figs. 5–8).

There are, however, some points of difference. On the aboral surface of an arm-bone (Pl. X. fig. 16) the cavity for the reception of the umbo of the opposed bone is large, and below it is a prominent ridge which passes downwards, in the median line, to the peg. The projection in the median line may be narrow or considerably swollen; and in either case the peg at the lower end is broad, projects aborally, and has a transparent, long and rather narrow articulating surface on each flank (Pl. X. figs. 16, 17; Pl. XI. figs. 21, 22). The surfaces project so much as to give the appearance of two lateral pegs; but that is not the case,

for there is but one, and it is concave at its lower part between the lateral articulating surfaces. Indeed, the breadth of the peg is very striking, as is also its amount of aboral projection. The expansion on either side of the ridge is considerable; and in some bones there is a swelling almost knob-like at the outer side of the usual socket for the knob of the next bone (Pl. X. figs. 16, 17, *k*). The adoral surface of a bone, corresponding to the aboral surface just noticed, has a broad, bluntly triangular projecting umbo (*u*) beneath the slot-shaped surface of the apophysis (Pl. X. figs. 18, 19). Below the umbo is a considerable depression for the median ridge of the opposed aboral surface, and the side continuation and its enlargements. The knobs (*k*) are large and project, and the cavity between them, and which merges below into the inferior notch, and which is for the reception of the broad peg, is rather large. The inferior notch is tall and wide. The apophysis is bent forwards above and is convex below. The upper muscle-fields of both surfaces are large, that of the aboral predominating, and the lower fields are, as is usual, small and oblique.

V. *Special and General Remarks upon the Muscles.*

Some of the muscles of *Ophiothrix variabilis* have already been noticed in the description of the specimens, but it is necessary to consider others and to refer slightly to all. It is evident that the muscular development and distribution is not similar in all Ophiuridæ. Simroth has given the muscles of *Ophiactis virens* his careful attention, and his descriptions are very valuable ("Anat. und Schiz. der *Ophiactis virens*, Sars," Zeitschr. f. wiss. Zool. Bd. xxvii. p. 417, 1876).

The muscles of the teeth ("interradiales adorales superiores"), according to Simroth's type, arise from the upper part of the adoral edge of the adjoining mouth-frames external to the jaw-plate or torus. There is one muscle to a tooth, and it may have a double insertion into the base of the tooth, there being two horizontal foramina in the jaw-plate at the base of the tooth, or a single one, the double foramen then being absent and represented by a slit.

In *Ophiothrix variabilis*, however, there are four and sometimes five depressions, diminishing in size from above downwards, in the substance of the adoral vertical edge of each mouth-frame (Pl. X. fig. 8); and consequently, when the two mouth-frames are combined, there is a double series of cavities placed side by side. A

muscle arises in each of the depressions (fig. 8, *c*), and the fibres pass adorally through the foramen in the jaw-plate, which is internal to them, and are attached to one side of the hollowed-out base of a tooth (figs. 3, 6, 7). The muscles are radial in direction, and there are two of them to each tooth, and eight in all. They are evidently the interradiales adorales superiores; and their action, by becoming tense and contracting, would be to fix the teeth tightly on the jaw-plate, so that they could project horizontally. On the other hand, as the muscles become lax, the bases of the teeth would be less tightly in contact with the jaw-plate, and some movement, up and down, of the free edge of the teeth would be possible. A muscle attaches the outside edges of the jaw-plate, on the brachial as well as the interbrachial sides, to the vertical processes (jaws) or adoral ends of the mouth-frames in the lower half; it arises from the oblique grooves near the edge, and is inserted on the edge of the jaw-plate. There are, according to Simroth, muscles between the vertical broad groove, formed by the union of the adoral surfaces of the jaws (fig. 8), and the aboral surface of the jaw-plate, and it is possible that they exist in *Ophiothrix variabilis*, but I have not verified the fact; at the same time there is connective tissue in the vertical groove uniting the conjoined skeletal parts.

The "interradiales aborales" (Pl. X. fig. 1, *mi*) are the largest and most important muscles of the mouth-frame regions; the fibres are not radial in direction, but conform in direction to the circle formed by the adjacent mouth-frames. The fibres arise on the interradial flank of one, and are inserted into the flank of the opposite mouth-frame, that is, on the other side of the interbrachial space. The greater part of the flanks is covered, and the fibres extend below to between the unjoined edges of the side mouth-shields, and touch the adoral edge of the mouth-shield at the median line.

I have not found any muscular fibres in the space between the brachial flanks of the mouth-frames, such as the "radiales" of Simroth, although their existence is evident in *Ophiactis*.

It is not necessary to do more than mention the existence of the adductor and retractor muscles of the genital plate and radial shield, since they have already been described. They are not mentioned by Simroth as occurring in his type. Lyman gives some excellent drawings of the adductores, but does not mention the retractor, which is, however, very visible in some

forms. Ludwig appears to be the only describer of retractores, of which he gives a very diagrammatic view.

The little slips of fibres, possibly muscular, which connect the genital scale with the genital plate and the radial shield are formed of very delicate fibres which differ materially from those of the adductores for instance, but neither set is striated. It will be interesting to seek these unimportant slips in other species of *Ophiothrix*. (I have not found them in the British species.)

The muscles of the upper and lower fields of the arm-bones are large, and are readily seen in broken-across joints. There is a good deal of connective tissue, more or less fibrous, extending from the adoral to the aboral surfaces of opposed bones; and it is attached at the edges of the median projection and of the lateral continuation of the aboral surface, and to the edges of the umbo and median edges of the muscle-fields in the adoral surface.

Besides this tissue two sets of muscles are visible in well-preserved specimens. One set is a single stout fibre on either side of the ridge leading down to the peg, and it arises above and a little external to the socket for the knob of the adoral bone (Pl. X. fig. 16, *m*). Its direction is almost from within outwards, and it is attached to the side of the depression below the umbo.

The other set of muscles arise from the sides of the convex aboral surface of the apophysis, and they pass on either side to be attached to the edges of the upper muscle-field on the side of the adoral surface. The fibres are numerous, and there appear to be two sets of them, one being higher up than the other (Pl. XI. figs. 25, 26, 27). They appear to be necessary in order to restrain the lateral dislocation of the apophysis. They occur in all the Mergui Ophiothrices.

VI. *The Arm-bones of* Ophiocampsis pellicula, *Dunc.*

The absence of upper arm-plates and the ability of the arms to curl downwards would imply that the arm-bones could not be made exactly upon the Ophiothrician type. The opposed surfaces of the arm-bones are remarkable; and the first thing that strikes the eye is the enormous upper muscle-area on the aboral surface of the arm-bones (Pl. XI. fig. 23). The lower area is decidedly small, and the tentacle-opening is large near the disk and smaller further out. The next point to be observed is the upper and aborally projecting apophysis, which is like that of *Ophiothrix*,

but possibly more inclined than is usual in that genus. The hollow for the reception of the umbo of the opposed arm-bone is deep and long from above downwards, and it occupies all the median line as far down as the upper edge of the notch of the inferior canal. There is no "peg." On either side of the hollow for the umbo is a raised, rounded ridge extending from the apophysis downwards and on either side to reach the outer part of the upper edge of the lower muscle-area. On each rounded ridge is a nodule situated far above the notch for the lower canal (Pl. XI. fig. 23), so that a nodule occurs on either side of the median hollow for the umbo, and it is placed above the origin of the downward projecting roots of the canal-notch. The nodules are slightly elongate and project aborally, and are articulating surfaces. Beyond the nodules, on the side remote from the median line, are slight depressions.

The lower canal is large, and the edges of the lower muscle-area are raised.

On the corresponding adoral surface of an arm-bone (fig. 24), the upper process, or slot for the reception of the apophysis of the adorally placed bone, is large. Below is a long umbo, rounded, broad and projecting in the upper part, narrow and with a median projecting narrow ridge midway, and tumid, broad and projecting at the lowest part, which is at the upper edge of the comparatively small lower canal. This long umbo is therefore most tumid, largest, and most projecting at its upper and lower extremities, and is narrow and less projecting midway.

There are no knobs on this surface, and the only approach to any such articulating process is a pair of indefinite enlargements where the upper edge of the lower muscle-area unites with the descending raised ridge of the sides of the lower canal. But the depressions for the nodules of the opposed aboral surface of the next bone are seen on the sides of the umbo close above its lower enlargement.

The absence of a peg or its analogue, the length of the hollow for the umbo, and the presence of a pair of nodules characterize this species in reference to the aboral surface of the arm-bone. On the other hand, the long umbo and the defective knobs of the adoral surface are just as peculiar *.

The large size of the slot and the obliquity of the apophysis

* The description is taken from joints near the disk; much modification occurs far out in the arm.

would enable great downward bending as well as lateral movement to occur; the long umbo and the corresponding socket would allow of a much greater amount of movement than is usual in *Ophiothrix* for instance, and the nodules on the aboral side would keep the umbo from slipping out.

DESCRIPTION OF THE PLATES.

Plate X.

Fig. 1. The upper part of the arm, four of the six arm-bones, mouth-frames, jaws, and teeth of *Ophiothrix variabilis*, nob. Magnified and partly diagrammatic. *g*, genital plate; *a*, top of arm-bones; *mf*, mouth-frame; *j*, jaw; *mi*, interradialis aboralis muscle of one side of the mouth-frames.

2. Jaw-plate, magnified, adoral surface. Foramina for the muscles, projections for the bases of the tooth-papillæ.

3. Side view of a longitudinal section made, radially, through teeth, jaw-plate, and jaw. *j*, jaw; *jp*, jaw-plate; *c*, depressions in the adoral surface of the jaw for the interradiales adorales muscles, which may be seen passing through the section of the foramina in the jaw-plate to the bases of the teeth, *t*. Diagrammatic and magnified.

4. Side and basal view of a large tooth-papilla. Magnified.

5. Lower surface of the uppermost tooth-papillæ.

6. Upper view of a tooth and of its base. Magnified.

7. The two upper foramina of a jaw-plate, showing muscle-slips coming out, to be inserted in the base of a tooth, one on each side, magnified.

8. Adoral view of combined jaws: *c*, depressions for the muscles. Below are the vertical ridges on either side of the central groove.

9. Under surface of the radial shield, magnified, showing the tuberosity, *t*, the ridge, *r*, for the retractor, and the remains of the adductor, *am*. Magnified.

10. Aboral end of the radial shield and genital plate: *r*, ridge for retractor; *r**, ridge for the same on the genital plate; *g*, head of genital plate, in contact above with the tuberosity of the radial shield; the fibres of the retractor are indicated. Magnified.

11. Side view of radial shield and genital plate. Same letters as before. Magnified.

12. Side view of the aboral end of the radial shield and genital plate, showing the small muscular slip, *m*, to the genital scale, which is not figured. Magnified.

13. Upperside of genital plate and shield: *gs*, genital scale; *ms*, muscle-slip from genital plate to shield; *am*, adductor muscle on its raised attachment. Magnified.

14. Under view of the genital plate, magnified.

15. Genital plate, side view towards the genital scale: *r**, ridge; *p*, nodule for articulation with the scale. Magnified.

Fig. 15*. Transverse section through the genital plate, magnified.

16. The central part of the aboral surface of an arm-bone of *Ophiothrix variabilis* not far from the disk, magnified. The apophysis has a triangular depression at its root for the umbo of the next bone; below is the median ridge ending in a broad double-faced peg. On either side of the ridge is a slender muscle, *m*, and at the side of the muscle remote from the median line the indefinite swelling, *k*.

17. The same view of an aboral surface, further out in the arm; the median ridge is nodular and broad above; the peg is double-faced and broad. The position of the muscle is on the edge of the sockets on the side of the median ridge. Magnified.

18. The aboral surface of the arm-bone opposed to fig. 17: *u*, the umbo, with a descending short part and a wide upper expansion; *k*, the knobs; between them is the arched hollow for the double-faced broad peg of the opposed bone. Magnified.

19. An aboral surface nearer the disk, and corresponding nearly with fig. 16: *s*, the upper part of the apophysis, with a slot or groove for the reception of the aborally placed apophysis; *u*, the large broad umbo, with a hollow below, and the knobs are placed on the side of the hollow for the peg. Magnified.

20. A view of the same from above obliquely downwards, showing the projecting umbo and knobs. The hollow below the umbo is not seen on account of the foreshortening. Magnified.

Plate XI.

Fig. 21. *Ophiothrix variabilis*. The double-faced peg, magnified.

22. The peg projecting, side view, magnified.

23. Arm-bone of *Ophiocampsis pellicula*, aboral surface near the disk: *u d*, the depression along the median line for the long umbo of the adoral surface of the next bone. The knobs are large, and the transverse ridges between the muscle-fields are well developed. Magnified. Diagrammatic.

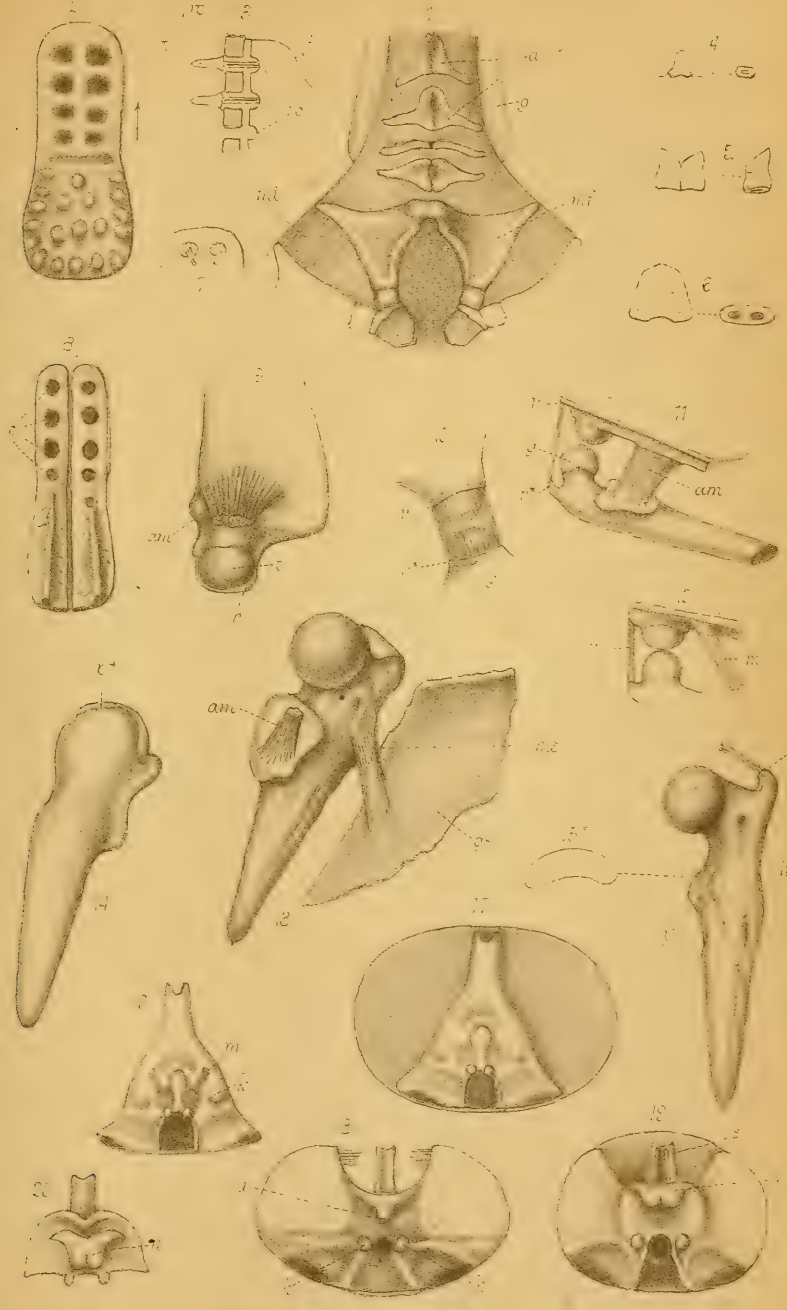
24. An adoral surface: *u*, the long umbo, with a projecting convex part above the lower notch; depressions for the knobs of the opposed surface on each side of the median umbo, just above the transverse inter-muscle-field ridges. Magnified. Diagrammatic.

25. Part of the aboral surface of an arm-bone of *Ophiothrix variegatus*, magnified, showing muscles attached to the sides of the apophysis, and passing transversely so as to be attached to the inner edge of the upper muscle-field. Magnified.

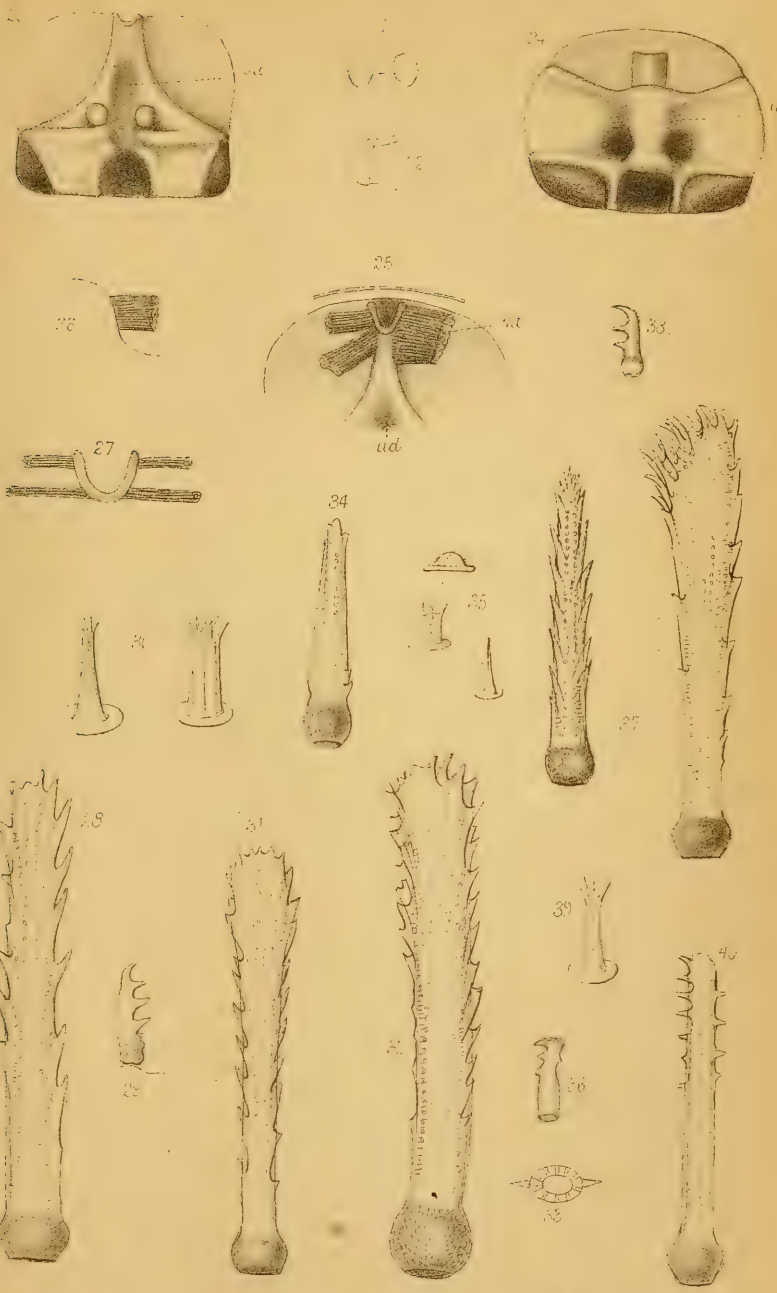
26. Muscle-fibres attached to the inner edge of the upper notch upon the upper muscle-field, magnified.

27. The apophysis, seen from above obliquely, showing the two layers of muscular fibres on the sides of its convex surface. Magnified.

(For description of figures 28–40 see page 106.)



STRUCTURE OF OPHIURIDÆ



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